

MP 711.03.23

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WEST VIRGINIA DEPARTMENT OF TRANSPORTATION  
DIVISION OF HIGHWAYS  
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

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MIX DESIGN FOR PORTLAND CEMENT CONCRETE

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1.0 PURPOSE

1.1 To establish a procedure for testing the physical properties of a proposed mix design.

1.2 To establish criteria for evaluating the test data to arrive at acceptable batch proportions for an approved mix design.

2.0 SCOPE

2.1 This procedure shall apply to the design of all portland cement concrete which is required by the specifications to be batched in accordance with an approved mix design with the exception of concrete specified in Section 603.

3.0 TEST PROCEDURE

3.1 The concrete mix design shall be performed in accordance with the applicable requirements of ASTM Designation C 192 by a Division approved laboratory. To obtain Division approval, a laboratory must demonstrate that they are equipped, staffed, and managed so as to be able to batch and test portland cement concrete in accordance with applicable ASTM Methods of Test. The most expeditious means of demonstrating such ability is by submission of a copy of their latest report of concrete and aggregate inspection by the Cement and Concrete Reference Laboratory, National Bureau of Standards, together with a letter detailing the actions taken to correct any deficiencies noted therein. A listing of approved laboratories is available on the WVDOT internet site.

3.2 The following information for each of the materials listed below that are to be used in the proposed mix design shall be listed in Attachment 1.

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Cement: Type, Source and Location, Source Code, Specific Gravity

Pozzolan: Type, Source and Location, Source Code, Specific Gravity

Chemical Admixtures: Type, Source and Location, Source Code

Coarse Aggregate: Type, Size, Source and Location, Source Code, Specific Gravity, Absorption, A-Bar, Unit Weight

Fine Aggregate: Type, Source and Location, Specific Gravity, Absorption, A-Bar, Fineness Modulus

3.2.1 The mass and volume of each material that is to be used in each batch shall be listed in Attachment 2.

3.3.2 The aggregate correction factor, as defined in AASHTO T 152, shall be listed in Attachment 3.

3.3 All classes of the concrete (except Class H and concrete for specialized overlays) for the proposed design shall be batched in at least four separate batches. Two of the batches shall be proportioned to produce a mix having the minimum cement factor, and two of the batches shall be proportioned to produce a mix having the minimum cement factor equal to the specified minimum plus one bag (94 lb (42.6 kg)).

3.3.1 Class H concrete and concrete for specialized overlays (as set forth in Section 679 of the specifications) for the proposed design shall be batched in at least two separate batches.

The batches for Class H concrete shall be produced at the cement factor for Class H concrete that is required in the specifications. The rapid chloride permeability test (in accordance with AASHTO T 277) specified in Section 601.3 shall be performed on each of these batches.

The batches for specialized concrete overlays shall be produced at (or above) the minimum cement factor specified in Section 679.2.2.1 or 679.2.2.2. The rapid chloride permeability test specified in Section 679.2.2 shall be performed on each of these batches.

3.3.2 When a Type A, D, F, or G admixture(s) is(are) used in a mix design, an additional batch of concrete (designated as a reference batch) shall be produced at the same cement factor, aggregate content, air content ( $\pm 0.5\%$ ), and consistency ( $\pm 0.5''$  (12 mm)) as the two batches produced in section 3.3 (or 3.3.1) at the minimum cement factor, but the Type A, D, F, or G admixture(s) shall not be included in this

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reference mix. The water content of this reference mix may exceed the maximum water content specified in Table 601.3.1A. This reference mix is necessary to fulfill the requirements of Sections 707.2.2.1 and 707.3.2.1.

- 3.4 Each batch of concrete shall be tested in the plastic state for air, consistency and yield. Each batch shall be adjusted as necessary to produce a plastic concrete having an air content, consistency, and yield equal to the specified value plus or minus a reasonable laboratory working tolerance. The following tolerances shall be used as a guide: Air content,  $\pm \frac{1}{2} \%$ ; Consistency,  $\pm \frac{1}{2}''$  ( $\pm 12$  mm) of slump or ball penetration; Yield,  $\pm 2\%$ .
- 3.5 When the properties of a concrete batch have been established within acceptable limits, seven 6" x 12" (150 mm x 300 mm) concrete cylinders shall be made from each batch produced in Section 3.3 (or 3.3.1) and 3.3.2 and tested in compression at the following ages: one cylinder at age 24 hours  $\pm 4$  hours (the exact age to the nearest hour at time of test shall be noted on the report); one cylinder at age 3 days; one cylinder at age 7 days; one cylinder at age 14 days; and three cylinders at age 28 days. The values of the physical properties of each mix shall be the average of the physical properties established in each of the two batches produced in section 3.3 (or 3.3.1). These values shall be listed in Attachment 3.
- 3.5.1 If it is desired to use 4" x 8" (100 mm x 200 mm) cylinders as the basis for acceptance (or early strength determination) in the field, in accordance with section 601.4.4, then seven 4" x 8" (100 mm x 200 mm) cylinders shall be fabricated and tested as outlined in section 3.5 for both of the trial batches at the minimum cement factor (in addition to the seven 6" x 12" (150 mm x 300 mm) cylinders).
- 3.5.1.1 If the average compressive strength of the six 28-day 4" x 8" (100 mm x 200 mm) cylinders for the batches at the minimum cement factor is not more than 10.0% greater than the average compressive strength of the six 28-day 6" x 12" (150 mm x 300 mm) cylinders for the batches at the minimum cement factor, then 4" x 8" (100 mm x 200 mm) cylinders will be permitted to be used in the field. Otherwise, any cylinders fabricated in the field (for acceptance or early strength determination) must be 6" x 12" (150 mm x 300 mm).
- The following formula shall be used during the mix design approval process to determine if the average compressive strength of the 4" x 8" (100 mm x 200 mm) cylinders is more than 10.0% greater than the average compressive strength of the three 28-day 6" x 12" (150 mm x 300 mm) cylinders:

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If  $X_{6 \times 12} \times 1.10 < X_{4 \times 8}$ , then 4" x 8" (100 mm x 200 mm) cylinders are not permitted to be used in the field

$X_{4 \times 8}$  = Average 28-day compressive strength of 4" x 8" (100 mm x 200 mm) cylinders

$X_{6 \times 12}$  = Average 28-day compressive strength of 6" x 12" (150 mm x 300 mm) cylinders

- 3.5.2 The following properties of each batch of concrete produced in Sections 3.3 (or 3.3.1) and 3.3.2 shall be listed in Attachment 2: A-Bar of Total Solids, Consistency, Air Content, Unit Weight & Yield, Water / Cement Ratio, and Temperature.

#### 4.0 ACCEPTANCE CRITERIA

- 4.1 If the Standard Deviation of the concrete plant production has been established, the mix design must have an average laboratory compressive strength (based on the 6" x 12" (150 mm x 300 mm) cylinder results) equal to or greater than the "Design 28-Day Compressive Strength" required by the specifications plus two times the Standard Deviation. Data used to establish the Standard Deviation shall be taken from the Division's data bank and shall consist of at least 30 individual test results obtained from recent plant production of concrete with proportions similar to the design mix. Information relative to the statistics for a particular plant will be furnished the Contractor upon request.

- 4.2 If the Standard Deviation of the concrete plant production has not been established (or in the case of mobile mixer units), the design mix must have an average laboratory compressive strength equal to or greater than the "Design 28-Day Compressive Strength" plus 1300 psi (9 MPa).

- 4.3 It is noted that the "Design 28-Day Compressive Strength" required by the Specifications is the minimum field strength sought in 6" x 12" (150 mm x 300 mm) or 4" x 8" (100 mm x 200 mm) cylinders representing the concrete being placed in the field, and should not be confused with the laboratory compressive strengths required for design.

#### 5.0 PROPORTIONING DESIGN MIX

- 5.1 If the average of the batches produced in Section 3.3 (or 3.3.1), with the specified minimum cement factor, satisfies the acceptance criteria (Section 4), then it will be considered acceptable as the design mix for the class of concrete being designed.

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- 5.2 If the average of the batches produced in Section 3.3 with the specified minimum cement factor does not satisfy the acceptance criteria (Section 4), then a linear compressive strength-cement factor relationship will be established using the average 28-day compressive strength (based on the 6" x 12" (150 mm x 300 mm) cylinder results) of the batches with the minimum cement factor and the average 28-day compressive strength of the batches with the minimum plus one bag cement factor. This relationship will be interpolated to determine a cement factor (to the nearest 1 lb (2.2 kg)) which would cause the acceptance criteria to be satisfied. This interpolated cement factor will be considered acceptable for proportioning the design mix for the class of concrete being designed.
- 5.2.1 If neither of the averages of the batches produced in Section 3.3 satisfies the acceptance criteria (Section 4), then that proposed mix design cannot be considered as acceptable, and a new mix design will be required.
- 5.2.2 Since all of the batches for Class H concrete (in Section 3.3.1) are produced at the cement factor that is required in the specifications, and batches at the target cement factor plus one bag (and corresponding permeability tests) are not produced for specialized overlay concrete, the linear interpolation outlined in Section 5.2 does not apply to Class H concrete or specialized overlay concrete.
- Therefore, if the average compressive strength of the Class H (or specialized overlay concrete) batches in Section 3.3.1 does not satisfy the acceptance criteria (Section 4), then that proposed mix design cannot be considered as acceptable, and a new mix design will be required.
- 5.3 The submittal for a proposed mix design shall include completed copies of Attachments 1 and 3. It shall also include a completed copy of Attachment 2 for the reference batch, a completed copy of Attachment 2 for each of the batches at the minimum cement factor, and a completed copy of Attachment 2 for each of the batches at the minimum cement factor plus one bag (when applicable). All pertinent information supporting these attachments and pertaining to the information in them should be submitted also.
- 5.4 Although the Contractor has satisfied all requirements for concrete design and a design mix has been approved by the Engineer, the Contractor may still be required to adjust the approved design mix in the field as necessary to maintain all properties within the limits of the specification. These field adjustments shall include increasing the cement factor above the value specified in the approved design mix if such an adjustment would be necessary to cause the strength of the field placed concrete to conform to the requirements of the specification.

- 5.4 Although the Contractor has satisfied all requirements for concrete design and a design mix has been approved by the Engineer, the Contractor may still be required to adjust the approved design mix in the field as necessary to maintain all properties within the limits of the specification. These field adjustments shall include increasing the cement factor above the value specified in the approved design mix if such an adjustment would be necessary to cause the strength of the field placed concrete to conform to the requirements of the specification.
- 6.0 MIX DESIGN RE-APPROVAL
- 6.1 Each mix design shall remain approved for a period of three years from the date of approval, after which the mix design may be re-approved for an additional three year period based on re-qualification tests (outlined in section 6.2) conducted at the Concrete Producer. If a mix design is used often enough (at least ten air content, slump, and compressive strength tests each year for the previous three year period), the re-qualification tests shall not be required, and the mix design may be re-approved based on the actual field tests performed during the previous three year period.
- 6.1.1 Concrete mixes for which the rapid chloride permeability test is required shall be re-approved at the same frequency as noted in section 6.1, but a re-qualification test (outlined in section 6.2.3) for the rapid chloride permeability test need only be performed once every six years.
- 6.2 The following procedures shall be used to re-approve concrete mix designs that do not meet the criteria in section 6.1.
- 6.2.1 The Concrete Producer shall provide a statement to the Engineer verifying that all sources of materials used in the approved mix designs are unchanged and the same as used in the original approved mix design. All materials shall meet the applicable sections of the specifications.
- 6.2.2 Coarse and fine aggregate samples shall be obtained at the Concrete Producer's facility in accordance with MP 700.00.06, and the following tests shall be conducted on those aggregate samples: specific gravity (both coarse and fine aggregate), combined A-bar of total solids, absorption (both coarse and fine aggregate), fineness modulus (fine aggregate), and unit weight (coarse aggregate). The results of these tests shall be used by a certified PCC Technician at the Concrete Producer to establish a new target A-bar for the mix and, if necessary, to adjust any batch volumes.

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- 6.2.3 The Concrete Producer shall then, at the Producer's facility and in the presence of WVDOH District Materials personnel, produce a representative batch (acceptable to both the Producer and the WVDOH personnel) in accordance with sections 601.6 and 601.7, of no less than 6 yd<sup>3</sup> of the concrete mix subject for re-approval. This batch shall be tested for air content, slump, unit weight and yield. Also, one set of 6" x 12" (150 mm x 300 mm) 28-day compressive strength specimens, and if applicable, two rapid chloride permeability specimens (each to be tested at an age of 90 days or earlier and the average result used) shall be fabricated and tested from this batch.
- 6.2.4 If a Concrete Producer desires to have the option of using 4" x 8" (100 mm x 200 mm) cylinders in the field for a mix design which has already been approved, then at the time of mix design re-approval (or at any time prior to that time), three additional 6" x 12" (150 mm x 300 mm) 28-day compressive strength specimens and six 4" x 8" (100 mm x 200 mm) 28-day compressive strength specimens shall be fabricated and tested from the batch produced in section 6.2.3. The six 6" x 12" (150 mm x 300 mm) cylinders shall then be compared to the six 4" x 8" (100 mm x 200 mm) cylinders as outlined in section 3.5.1.1 in order to determine if 4" x 8" (100 mm x 200 mm) will be permitted in the field for the subject mix design.
- 6.3 The results of all tests required and the proportions used in the batch (outlined in section 6.2) shall be recorded in the applicable sections of Attachments 1, 2, and 3 and submitted to MCS&T Division for evaluation. Based on these results, the existing mix will either be re-approved (possibly with slight adjustments), or the current mix design will be considered to have expired and a new mix design will be required.
- 6.3.1 For mix design re-approval purposes, the compressive strength of the representative batch produced in section 6.2.3 must meet or exceed the Design 28-day compressive strength in section 601.3 of the specifications, but it does not have to meet the "overdesign" acceptance criteria outlined in section 4.0.
- 6.3.2 For mix design re-approval purposes, the average of the two rapid chloride permeability test results from the representative batch produced in section 6.2.3 must be 1000 coulombs or less in order for the mix design to be re-approved.

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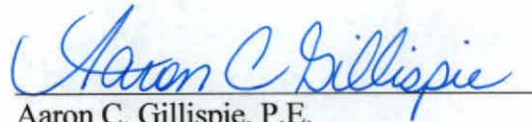
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6.3.3

If a mix design has expired, it may still be used on projects which have started before the mix design expired. However, after its date of expiration, a mix design may not be used on any new projects; a new mix design shall be required for these projects.



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Attachments

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ATTACHMENT 1

Source: \_\_\_\_\_

Source Location: \_\_\_\_\_

Design Laboratory: \_\_\_\_\_

Class of Concrete: \_\_\_\_\_

Date: \_\_\_\_\_

Cementitious Material Data			
Data	Cement	Pozzolan 1	Pozzolan 2
Name			
Type			
Source			
Source Location			
Source Code			
Specific Gravity			

Admixture Data			
Data	Air Entrainment	Additional Admixture 1	Additional Admixture 2
Name			
Type			
Source			
Source Location			
Source Code			

Aggregate Data		
Data	Coarse Aggregate	Fine Aggregate
Class/Size		
Type		
Source		
Source Location		
Source Code		
Specific Gravity		
A-Bar		
Absorption		
Fineness Modulus		
Unit Weight		

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ATTACHMENT 2

Source: \_\_\_\_\_

Source Location: \_\_\_\_\_

Design Laboratory: \_\_\_\_\_

Class of Concrete: \_\_\_\_\_

Date: \_\_\_\_\_

Check The Appropriate Box For Designated Batch:	Reference Batch	Minimum Cement Factor		Minimum Cement Factor + 1 Bag		Additional Batch
		Batch 1	Batch 2	Batch 1	Batch 2	

Material	Mass	Units	Volume	Units
Cement		lb (kg)		ft <sup>3</sup> (m <sup>3</sup> )
Pozzolan 1		lb (kg)		ft <sup>3</sup> (m <sup>3</sup> )
Pozzolan 2		lb (kg)		ft <sup>3</sup> (m <sup>3</sup> )
Latex Admixture		lb (kg)	gal (L)	ft <sup>3</sup> (m <sup>3</sup> )
Water		lb (kg)	gal (L)	ft <sup>3</sup> (m <sup>3</sup> )
Air Content, by volume		%		ft <sup>3</sup> (m <sup>3</sup> )
Coarse Aggregate		lb (kg)		ft <sup>3</sup> (m <sup>3</sup> )
Fine Aggregate		lb (kg)		ft <sup>3</sup> (m <sup>3</sup> )
Total		lb (kg)		ft <sup>3</sup> (m <sup>3</sup> )
Air Entrain. Admixture		oz/Cwt (mL/100kg)		fl. oz. (mL)
Chemical Admixture 1		oz/Cwt (mL/100kg)		fl. oz. (mL)
Chemical Admixture 2		oz/Cwt (mL/100kg)		fl. oz. (mL)

## Mixture Test Data

A Total Solids	W/C Ratio	Cement Factor	Temperature	Consistency	Air Content	Unit Weight	Yield

## Compressive Strength, psi (MPa)

Specified Test	Actual Test Age (hours)	6" x 12" (150 x 300 mm) Strengths	4" x 8" (100 x 200 mm) Strengths
Age:			
24 ± 4 Hours			
3 Days			
7 Days			
14 Days			
28 Days			
28 Days			
28 Days			
Avg. 28 Day Strength			

Rapid Chloride Permeability Testing  
(When Applicable)

Age at Time of Test (Days)	Total Adjusted Charge Passed (Coulombs)

# SUMMARY

Source: \_\_\_\_\_  
Source Location: \_\_\_\_\_  
Design Laboratory: \_\_\_\_\_  
Class of Concrete: \_\_\_\_\_  
Date: \_\_\_\_\_

Material	Reference		Minimum Cement Factor		Minimum Cement Factor + 1 Bag	
	Mass	Units	Mass	Units	Mass	Units
Cement		lb (kg)		lb (kg)		lb (kg)
Pozzolan 1		lb (kg)		lb (kg)		lb (kg)
Pozzolan 2*		lb (kg)		lb (kg)		lb (kg)
Water		lb (kg)		lb (kg)		lb (kg)
Coarse Aggregate		lb (kg)		lb (kg)		lb (kg)
Fine Aggregate		lb (kg)		lb (kg)		lb (kg)
Total		lb (kg)		lb (kg)		lb (kg)
Air Entrain. Admixture		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)
Chemical Admixture 1		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)
Chemical Admixture 2		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)		oz/Cwt (mL/100kg)
Total A Bar Solids						
Water Cement Ratio						
Cement Factor						
Temperature		°F (°C)		°F (°C)		°F (°C)
Consistency		inches (mm)		inches (mm)		inches (mm)
Air Content		%		%		%
Unit Weight		lb/ft <sup>3</sup> (kg/m <sup>3</sup> )		lb/ft <sup>3</sup> (kg/m <sup>3</sup> )		lb/ft <sup>3</sup> (kg/m <sup>3</sup> )
Yield		ft <sup>3</sup> (m <sup>3</sup> )		ft <sup>3</sup> (m <sup>3</sup> )		ft <sup>3</sup> (m <sup>3</sup> )
Aggregate Correction Factor per AASHTO T 152				%		%

Compressive Strength, psi (Mpa)	Reference Batch	Minimum Cement Factor Batch		Minimum Cement Factor + 1 Bag Batch
		6" x 12" Cyl. (150x300 mm)	4" x 8" Cyl. (100x200 mm)	
1 Day				
3 Days				
7 Days				
14 Days				
28 Days				
28 Days				
28 Days				
Avg. 28 Day Strength				
If applicable, are 4" x 8" (100 x 200 mm) cylinders permitted in the field:				
Average Value of Rapid Chloride Permeability Test (Coulombs):				